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Yoga Therapy and Heat Regulatory and Cardiovascular Systems of a Human Body

N.S. Lodhi[1], Padam Sharma[2] and V.P. Saxena[3]
[1]Sagar Institute of Research, Technology and Science – Pharmacy,
Sagar Group of Institutions, Ayodhya Bypass Road Bhopal, (Madhya Pradesh), India.
[2]Government Girls College, Hoshangabad Road, Seoni Malwa, (Madhya Pradesh), India.
[3]Sagar Institute of Research, Technology and Science,
Sagar Group of Institutions, Ayodhya Bypass Road Bhopal, (Madhya Pradesh), India.

(Corresponding author: V.P. Saxena)*
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ABSTRACT: Human body undergoes physiological changes during abnormal atmospheric conditions and mental stress. This includes excessive hot and cold conditions of climate and emotional shocks. This causes changes in body circulations in human beings and heat regulatory disturbance in outer parts. This causes imbalances in both the systems which leads to ailments.
Yoga therapy is one which is very effective in both the cases. This paper presents biophysical processes of heat regulation and blood circulation in a human body, in particular under severe cold conditions. This is followed by Yoga exercises with potential therapic values to control both the processes under abnormal conditions of the thermal environment. A mathematical model has also been discussed with relates atmospheric conditions with flow rate and temperature of the blood.

Keywords: Yoga Therapy, Mathematical Model, Yogic Exercises

I. INTRODUCTION

Yoga is a science practiced in South Asian countries over thousands of years. It produces consistent physiological changes and have scientific basis [1]. All over the world scientists have extensively studied Yoga and claimed that it increases longevity [1, 2, 3, 4]. It has therapeutic and rehabilitative effects [5, 6, 7, 8]. Yogic exercises are being used as preventive measures for many diseases like fluctuating blood pressure, nervous disorders, regulating heat regulation during extreme climatic conditions, abdomen disorders caused by internal organs.
Cardio-vascular systems hold a key position in interpretation of changes throughout the body (Fig. 1).

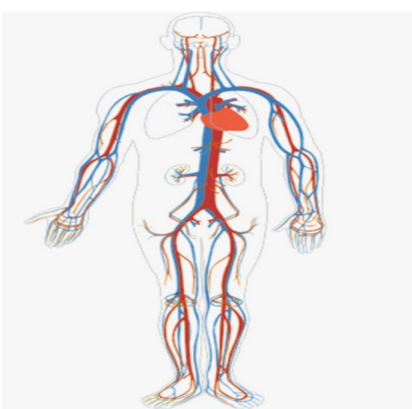

Fig. 1. Major blood vessels in a human body.

As the age advances cardio-vascular regulatory mechanisms reduces their efficiency.
Similarly, heat regulation and temperature control system also under goes variations with blood circulation. This is visible more due to changing climate conditions and nervous situations. The heating system of the body is inflamed by several facts and the peripheral parts of human body is inflamed most. (Fig. 2).

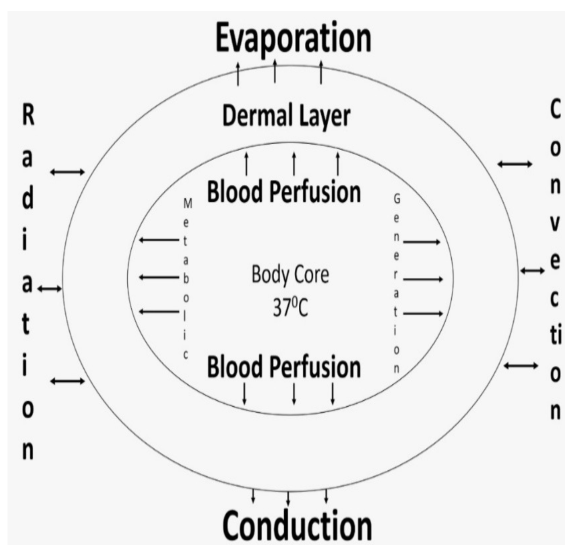

Fig. 2. Heat balance in a human body.

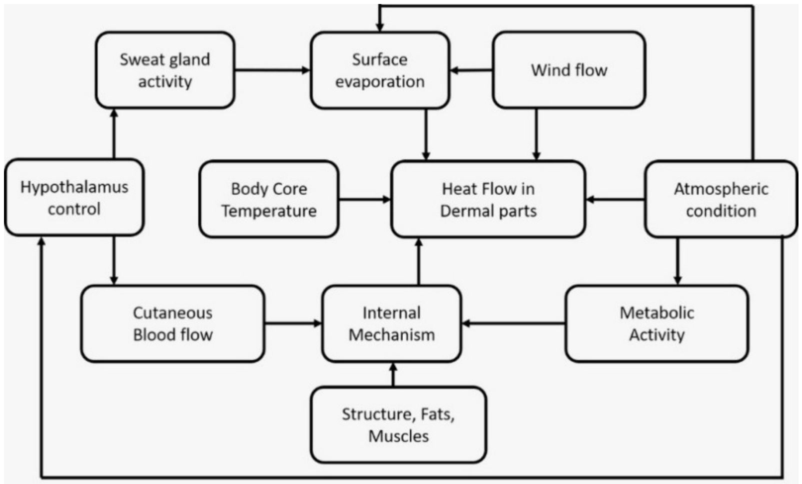

Fig. 3. Flow chart for heat regulation.

A schematic diagram of comprehensive effect of this dermal system is shown in Fig. 3. A board diagram of dermal blood circulation and heat flux is given in Fig. 4 a and b. Right from ancient times yoga experts from Indian subcontinent used asana to protect outer human body from climate onslaught to those living in Himalayas could sustain their health, even at the advanced age by cardio-vascular and thermal control of the body.

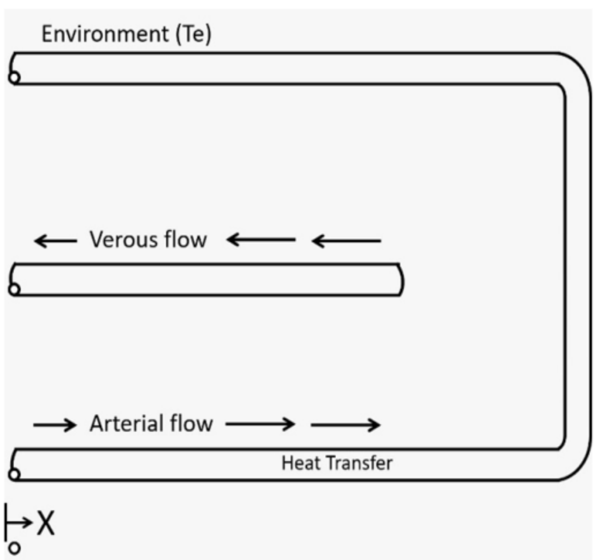

Fig. 4a. Heat flux from blood to environment.

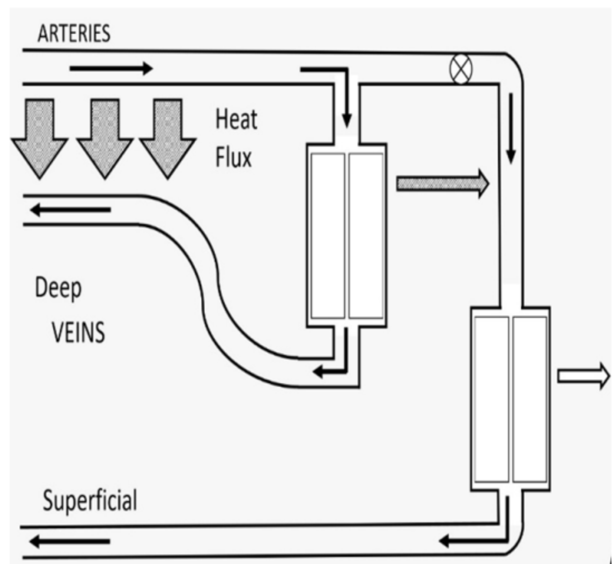

Fig. 4b. Heat flux to internal Dermal body parts.

II. YOGA THERAPY FOR EXTREME COLD

The sages were able to control these physiological processes through the neural network of the body. The signals are generated in the hypothalamus located inside the forehead where people use put a "*Tilak*" or "*Bindi*". The neural signals control blood vessel flexibility and dilated or constricts the same depending on climatic conditions in general and extreme heat or extreme cold conditions of the atmosphere. For example, during cold conditions the blood vessels of the outer body parts constrict so that minimum blood is available in dermal parts to be cooled by the atmosphere. Because excessive cold blood may damage the internal organs as well as the dermal tissue including thermal receptors, sweat glands and lymphatics. For normal humans prolonged exposure to cold may cause injuries and frostbites (Fig. 5).

Cold Injury

• Cold injury is a type of necrosis caused by excessive heat transferred from the human body to the environment.

• Ruch and Patton mentioned that the pain receptor due to cold activates if the skin surface temperature falls to 7°C.

• A sedentary nude man feels uncomfortably cold, shivering cold and extremely cold when the mean skin temperature is respectively 31°C, 30°C and 29°C.

• The amount of tissue destruction is based on the low degree of temperature and the duration of exposure.

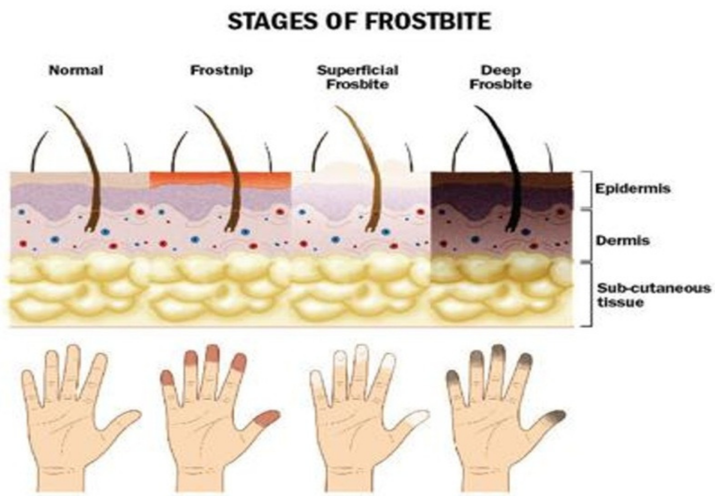

Fig. 5. Cold effect on human hand.

• The cold injury caused by cold can be divided into two groups:
– Those that occur without any freezing of the body tissue- Chilblain and Trench foot (Immersion injury)
– Those that results from the freezing of the skin or body part – Frostbite

Physical Behavior During Cooling of Tissue

• The intracellular water remains unfrozen while the extra cellular space crystallizes.

• The ice does not penetrate the cell membrane.

• Water is liberated through cell membrane which is permeable to water but impermeable to most of the solutes that are present and thus intracellular solute concentration increases and the solution becomes hypertonic.

• Hypertonic solutions in cellular space damage the structure.

• Porosity of the tissue increases.

The Consequences

• Due to these changes in micro-level caused by cooling, the inactive epidermis layer extends deeper and its thermal conductivity is changed to lower values and the water migration to the surface increases with more evaporation at the boundary surface. The metabolic heat generation rate falls due to increases in concentration of nutrients as evaporation takes water away. Solidification of water takes place in intracellular space. Blood circulation also behaves periodically on account of pressure on capillaries and arteries. Vasodilatation and Vasoconstriction take place alternatively.

• These cellular disturbances cause the change in parameters like, mass of blood flow rate and metabolic heat generation rate with time. The concerned parameters depend on time along with other independent variables.

• Frostbite occurs when there is freezing of the injured area and it occurs when the tissue temperature falls below 32°F or 0°C.

• When an area of the body freezes, ice crystals from within the cells. These ice crystals cause the cells to rupture, leading to cell death.

• Frostbite goes through several stages
– Frosrnip (First degree injury)
– Second degree injury
– Third degree injury

Therefore, below 4°C the blood vessels are dilated to keep these entities warm. But this is for a limited period [9]. In such cases yoga helps to control the supply to meet both the requirements. Another adverse effect of vessel constriction is that excess goes to larger and flexible blood vessel carrying additional pressure on the regulatory system of heart. Under very extreme cases it may lead to system break down and heart failure. Yogic exercises help in such situations also, we can find several sadhus, sages and other spiritual thinkers go to Himalayan high altitude regions and perform meditation for their mental health and salvation. Many of them do not wear clothes and perform meditation for months and years. This practice is going on since vedic and pre-vedic era. They use to survive with minimum food and enjoy longevity also. Of course they also know and use herbal medicines to get the strength. Saxena *et al.,* [10, 11] carried out several theoretical (Mathematical) studies related to above. The same can be further extended to find out the effect of Yoga therapy.

There are number of yoga positions (*Asanas*) recommended to counter the cold effect on human body. The information regarding this is available in the literatures. However, the guide lines available at different sources are not ways overlapping and do not suggest a discrete and streamlined recommended may be some of the experts do not reveal this information. Moreover, the numbers of manipulations of nerve signals for cardiovascular circulation and body heat regulation are practiced are practiced by selected Sadhus and Yogis are assumed to be still secrets and not found in commonly available texts. Here we give some selected yoga positions to prevent the effect of severe cold. *Pranayam* and *Kapalbhati* are practiced for all situations including cardiovascular and lung

circulation. Other additional *asanas* of positions are as follows.
1. *Sheershasana* (Head stand)
2. *Sarvangasana* (Shoulder stand)
3. *Nokasana* (Boat pose)
4. *Phalkasana* (Plank pose)
5. *Setubandh Asana* (Bridge pose)
6. *Utkatasana* (Twisted chair pose)
7. *Pashchimottasana* (Seated forward stand)

Above *asanas* can be performed simple learning.

These *asanas* will protect heart from extra pressure and will help extremities like lags, head and arms with regular blood supply.

Warming and Blood Circulation:

Circulation and smooth flow of blood in human body keeps the body warm. Normal blood circulation promotes all of our biological systems by delivering oxygen throughout the body and helping to keep it warm during winters. When circulation is inadequate or blood does not flow vigorously will make figures and legs cold. For mild cold conditions following known steps can improve the circulation.

(i) **Moderate to Brisk Walking**. Just 20 to 30 minutes of brisk walking regularly has shown to improve circular, particularly in legs and protects from cold effect by narrowing of arteries. This also improve your cardiovascular health.

(ii) **Deep Breathing Yogic Exercises.** Exercises like *Pranayam* and Chanting *Om* boosts circulation and pushes the blood to the system. Another pose which is very important is to lie down on the floor with bottom close to wall and but your feet to wall for 5 to 15 minutes. The exercise of reserve boat shape is also useful to enhance blood circulation in cold environment by cycling, swimming, hiking and dancing.

Case Studies of Yoga on Cardiovascular System

A group of experts (Bharshankar *et al.,* [12]) conducted practical examination on human subjects due to Yoga practice.

This study was conducted to examine the effect of yoga on cardiovascular function in subjects above 40 yrs of age. Pulse rate, systolic and diastolic blood pressure and Valsalva ratio were studied in 50 control subjects (not doing any type of physical exercise) and 50 study subjects who had been practicing yoga for 5 years.

From the study it was observed that significant reduction in the pulse rate occurs in subjects practicing yoga ($P < 0.001$). The difference in the mean values of systolic and diastolic blood pressure between study group and control group was also statistically significant ($P < 0.01$ and $P < 0.001$ respectively

Madanmohan *et al.,* [13] found modulation of cardiovascular response of Yogic exercises. This study reports the effects of yoga training on cardiovascular response to exercise and the time course of recovery after the exercise. Cardiovascular response to exercise was determined by Harvard step test using a platform of 45 cm height. The subjects were asked to step up and down the platform at a rate of 30/min for a total duration of 5 min or until fatigue, whichever was earlier. Heart rate (HR) and blood pressure response to exercise were measured in supine position before exercise and at 1, 2, 3, 4, 5, 7 and 10 minutes after the exercise. Rate-pressure product [RPP = (HR x SP)/100] and double product (Do P = HR x MP), which are indices of work done by the heart were also calculated. Exercise produced a significant increase in HR, systolic pressure, RPP & DoP and a significant decrease in diastolic pressure. After two months of yoga training, exercise-induced changes in these parameters were significantly reduced. After yoga training a given level of exercise leads to a milder cardiovascular response, suggesting better exercise tolerance.

A German group of researchers (Kerstin, Khattab [14]) carried out investigation on the effect of Yoga on Cardiac Parasympathetic Nervous Modulation. Relaxation techniques are established in managing of cardiac patients during rehabilitation aiming to reduce future adverse cardiac events. It has been hypothesized that relaxation-training programs may significantly improve cardiac autonomic nervous tone. However, this has not been proven for all available relaxation techniques. They tested this assumption by investigating cardiac vagal modulation during yoga.

Jertah *et al.,* from USA [15] studied physiological changes due to long *Pranayamic* breathing defined as a manipulation of breath movement, has been shown to contribute to a physiologic response characterized by the presence of decreased oxygen consumption, decreased heart rate, and decreased blood pressure, as well as increased theta wave amplitude in EEG recordings, increased parasympathetic activity accompanied by the experience of alertness and reinvigoration. The mechanism of how pranayamic breathing interacts with the nervous system affecting metabolism and autonomic functions remains to be clearly understood. The hypothesis indicates that voluntary slow deep breathing functionally resets the autonomic nervous system through stretch-induced inhibitory signals and hyperpolarization currents propagated through both neural and non-neural tissue which synchronizes neural elements in the heart, lungs, limbic system and cortex. During inspiration, stretching of lung tissue produces inhibitory signals by action of slowly adapting stretch receptors (SARs) and hyperpolarization current by action of fibroblasts. Both inhibitory impulses and hyperpolarization current are known to synchronize neural elements leading to the modulation of the nervous system and decreased metabolic activity indicative of the parasympathetic state. They propose pranayama's physiologic mechanism through a cellular and systems level perspective, involving both neural and non-neural elements. This theoretical description describes a common physiological mechanism underlying pranayama and elucidate the role of the respiratory and cardiovascular system on modulating the autonomic nervous system. Along with facilitating the design of clinical breathing techniques for the treatment of autonomic nervous system and other disorders, this model will also validate pranayama as a topic requiring more research.

These studies can further be extended to extreme climatic conditions.

TEMPERATURE ON BLOOD CIRCULATION AND TEMPERATURE DISTRIBUTION IN HUMAN BODY

Blood Flow in Extremities

The blood perusing the extremities passes outward from the heart along the arterial system, loses heat in the surface capillaries and returns to cool the body by mixing with venous blood from the warm internal organs. Heat lost in this manner can be reduced if the arterial and venous blood supplying the limb exchange heat through the vessel walls. Thus, the blood reaching the superficial regions is precooled and the capillary – surface gradient is reduced. Less heat is lost from the blood, while the venous blood returning to the heart is partially rewarmed. The net effect is to conserve heat. The Yoga exercises can help in this regards.

The extent of countercurrent exchange is controlled by the relative distribution of venous return from the extremities to the deep and superficial vessels. If the blood returns to the heart via the superficial veins, conductive transfer to the deep arteries is minimal. If the deeper veins are utilized for the venous returns, internal heat conservation is facilitated (Fig. 6).

A detailed mathematical study of dermal blood circulation dependent temperature regulation has been carried out by the first author (Saxena [21, 23]) and with other coworkers (Saxena & Arya [24] and Saxena & Pardasani [20]).

The phenomenon of countercurrent arterial venous exchange which precools or prewarms arterial blood plays a central role in the conservation or rejection of body heat. Tiwari under the supervision of Saxena [16] have conducted a detailed study in this aspect described below.

Mathematical Equations

Thermal balances on their model is given by the following differential equations:

Arteries:

$$m\frac{dT_A}{dx} + (h)_i(T_A - T_v) + (h)_A\,(T_A - T_e) = 0 \qquad (1)$$

Veins:

$$m\frac{dT_v}{dx} + (h)_i(T_A - T_v) + (h)_v\,(T_A - T_e) = 0 \qquad (2)$$

The boundary conditions are given by

$$T_A = T_0 \quad \text{at} \quad x = 0 \qquad (3)$$

And

$$T_A = T_v \quad \text{at} \quad x = l \qquad (4)$$

where

m = blood mass flow rate,
T_A = arterial blood temperature,
$(h)_i$, $(h)_A$ = heat transfer coefficient between arteries and veins and arteries and environment respectively
T_v = venous blood temperature,
T_e = environmental temperature,
l = length of the extremity,

Here some modifications have been made in this model. The mathematical model incorporates the effect of metabolic heat generation. The rate of metabolic heat generation is assumed to be arterial - environment and venous – environment temperature dependent respectively for arteries and veins. The Yogic exercises like deep Pranayam can control and have consequential effect of metabolic cell biochemistry limiting perspiration. The equations (1) and (2) can be reduced to the following form:

Arteries:

$$m\frac{dT_A}{dx} + (h)_i(T_A - T_v) + (h)_A\,(T_A - T_e) + S\,(T_A - T_e) = 0 \qquad (5)$$

Veins:

$$m\frac{dT_v}{dx} + (h)_i(T_A - T_v) - (h)_v\,(T_v - T_e) + S\,(T_A - T_e) = 0 \qquad (6)$$

The boundary conditions are given by (3) and (4). On non-dimensionalising equations (3), (4) and (6) by using-

$$X = \frac{(T_A - T_e)}{(T_0 - T_e)} \qquad Y = \frac{(T_v - T_e)}{(T_0 - T_e)} \qquad Z = \frac{x}{l}$$

for arteries and veins, these reduce to the following form:

$$\frac{dX}{dZ} + h_1\,(X - Y) + h_2\,X = 0 \qquad (7)$$

$$\frac{dY}{dZ} + h_3\,(X - Y) + h_4\,Y = 0 \qquad (8)$$

$$X(0) = 1 \qquad (9)$$

and

$$X(1) = Y(1) \qquad (10)$$

Solutions

The solutions for the arteries and veins are obtained in the following form:

$$X = e^{h_5 Z}\left[\frac{D_1 \cosh\{C_1(1-Z)\} + \sinh\{C_1(1-Z)\}}{D_1 \cosh C_1 + \sinh C_1}\right] \quad (11)$$

$$Y = e^{h_6 Z}\left[\frac{D_1 \cosh\{C_1(1-Z)\} + \sinh\{C_1(1-Z)\}}{D_1 \cosh C_1 + \sinh C_1}\right] \quad (12)$$

The values of constants $C_1$and D_1 and determined by using boundary conditions (9) and (10) and are given by:

$$C_1 = \frac{1}{2}\sqrt{(N_a + N_V)(N_a + N_V + 4h_1)}$$

$$D_1 = \sqrt{\left[\frac{N_a + N_V + 4h_1}{N_a + N_V}\right]}$$

Here, those regions are considered where the numbers of arteries and veins are almost equal their respective locations are same. Therefore, equations (11) and (12) can be solved by taking $N_a \cong N_V$. Accordingly we get the following solutions:

$$X = E[D_2 \cosh\{C_2(1-Z)\} + \sinh\{C_2(1-Z)\}]$$
$$Y = E[D_2 \cosh\{C_2(1-Z)\} + \sinh\{C_2(1-Z)\}]$$

where

$$h_1 = N_i + \frac{Sl}{m} \qquad h_2 = N_a$$
$$h_3 = h_1 + h_2 \qquad h_4 = N_V$$
$$h_5 = h_1 + h_4 \qquad h_6 = \frac{h_5 - h_3}{2}$$
$$N_i = \frac{(h)_i}{m} l \qquad N_a = \frac{(h)_A}{m} l$$
$$N_V = \frac{(h)_V}{m} l \qquad N_a = N_V = N_0$$
$$C_2 = N_0\sqrt{1 + 2\frac{h_1}{m}} \qquad D_2 = \sqrt{1 + 2\frac{h_1}{N_0}}$$
$$E = \frac{1}{D_2 \cosh C_2 + \sinh C_2}$$

RESULTS AND DISCUSSION

The numerical values have been taken from Mitchell *et al.,* [19] and Myers [18], Hodgson [17], and Saxena and Bindra [22] to obtain the numerical results which are as follows:

m = 0.0315 cal/cm^3- min.deg C

S = 0.018 cal/ cm^3 – min

T_b = 37°C

T_e = 33°C

h_1 = $N_i + 0.5$

The calculations have been performed for following three cases of N_0 and N_i

N_0	=	0,	0.1,	1.0
N_i	=	0,	0.1,	1.0

Fig -6 is for $N_0 = N_i = 0$, Fig -7 is for $N_0 = N_i = 0.1$, and Fig. 8 is for $N_0 = N_i = 1.0$. Temperature variation is very interesting for different sets of values of N_0's and N_i's. In general, little cooling of the arteries or venous flow exists for low values of N_0 . This may be due to the values of N_0 and N_i which are zero (Fig. 6). For $N_0 = N_i = 0.1$, the arterial blood undergoes a significant temperature drop (Fig. 7). The fall in temperature is more for higher values of N_0 and N_i (Fig. 8).

Also we can see that the venous blood not only fails to rewarm but continues to cool off when $N_i = 0$ (Fig. 6) and N_i is large then substantial rewarming of venous blood will occur (Fig. 7, 8).

There is slight change in our results for $N_0 = N_i = 0.1$ and $N_0 = N_i = 1$ as compared to the results obtained by Mitchell *et al.,* [19]. This may be due to the effect of metabolic heat generation that we have taken arterial – venous – environmental temperature dependent. In the earlier model this term was neglected.

Saxena *et al.,* [21, 23] has carried out detailed theoretical study of temperature distribution in dermal region in relation with blood circulation. Later on, this study was extended to more realistic conditions [20, 22, 24].

The mathematical and numerical results do not indicate the direct effect of Yogic exercises on the temperature variation and tissue blood mass flow rate. However, we can generate such relationships in future studies. We can also relate T_A , T_v and T_e and predict effect of environmental conditions on temperature and blood flow rate m and then incorporate the effect of specific Yogic asanas. Thus we can develop Yoga therapy to protect human body in general and outer body parts in particular.

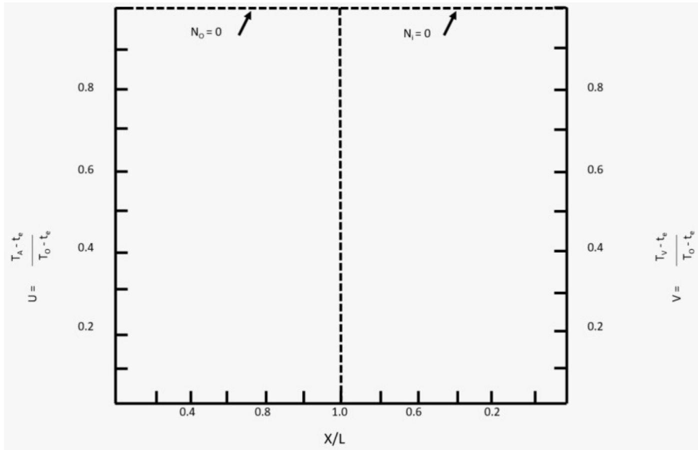

Fig. 6. Numerical result for $N_0 = 0$ and $N_1 = 0$.

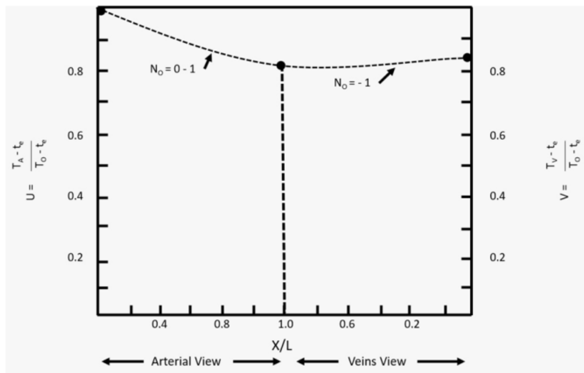

Fig. 7. Temperature change for $N_0 = 0.1$.

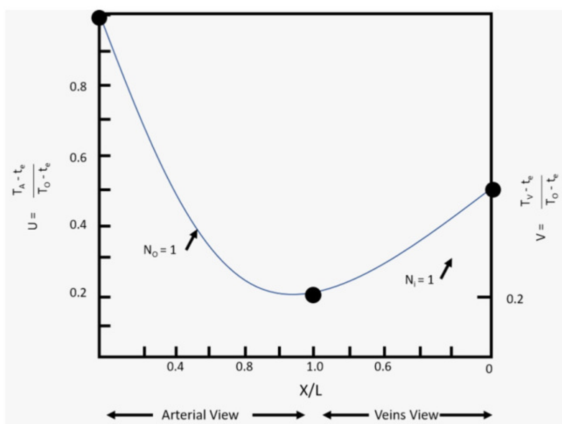

Fig. 8. Temperature distribution for $N_0 = 1$ and $N_1 = 1$.

Overall Unification of Approaches

This paper is an attempt to bring three diversified approaches, namely:

A. Physiological Situations

B. Practical Case Studies

C. The graphical (Mathematical) support and Applications

We do not claim that it is a well-knit comprehensive research leading to scientific approaches to field applications of Yogic exercise to bring out hidden relationships. But we have given to take-off ground for the above approaches.

With this idea we can endeavor to create new approach for comprehensive study of Yogic Therapy for care and prevention of physiological disorders related to cardiovascular circulation and orthopedic situations. Thus we can explore following sequence:

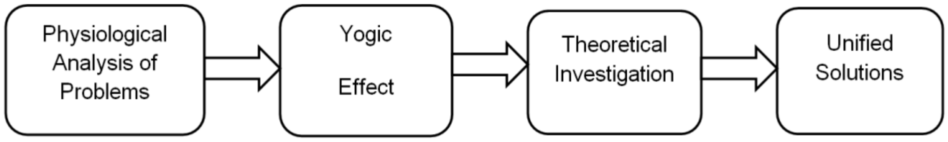

Fig. 9. The Integrated Approach of Yoga Therapy.

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Conflict of Interest. None

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